9

Biological Services Program

FWS/OBS-76/20.9
July 1980

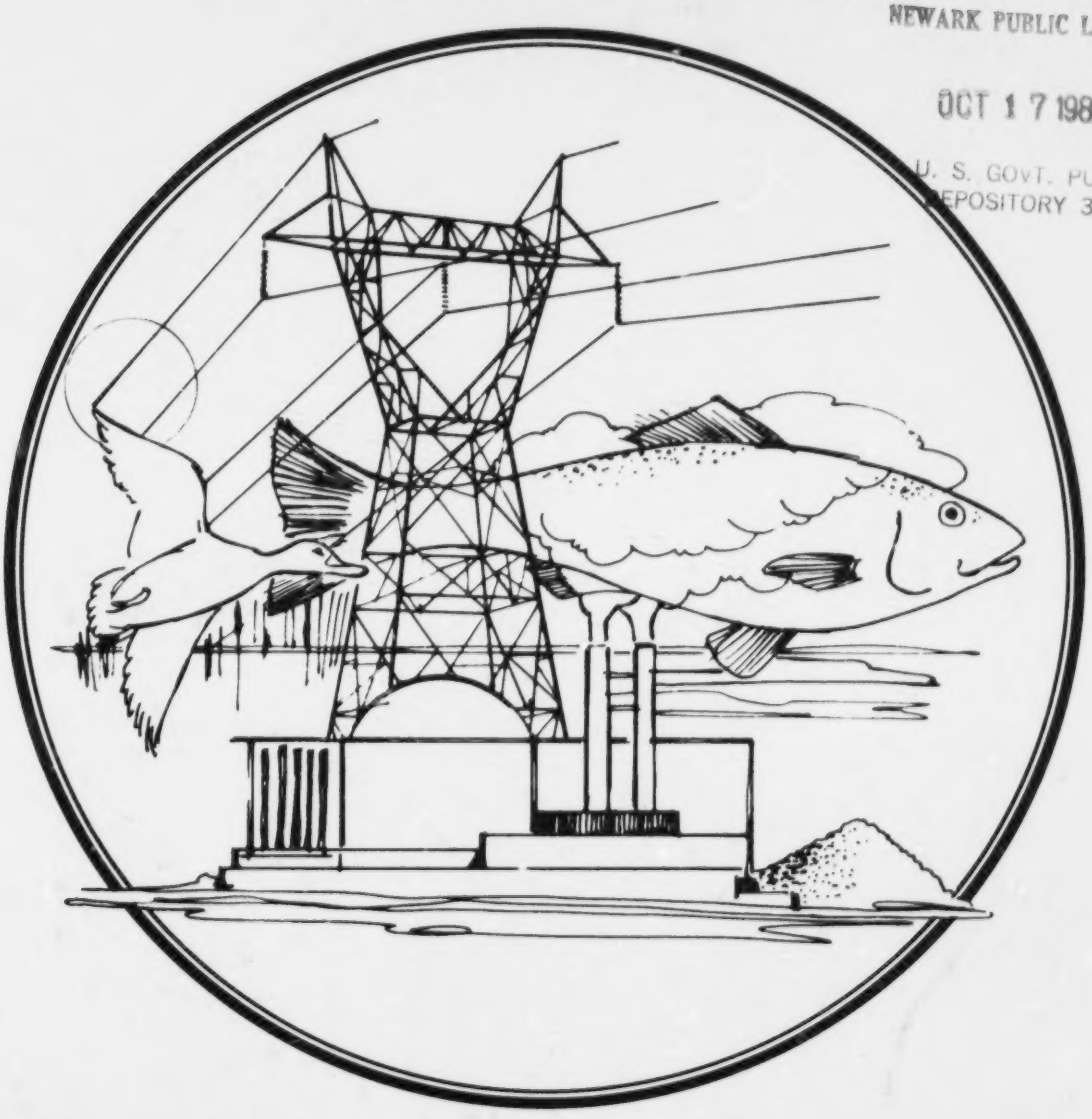
Topical Briefs: Fish and Wildlife Resources
and Electric Power Generation, no. 9

Cooling Water Intake Screening Devices Used to Reduce Entrainment and Impingement

NEWARK PUBLIC LIBRARY

OCT 17 1980

U. S. GOVT. PUBS.
DEPOSITORY 376



Fish and Wildlife Service

U.S. Department of the Interior

I 49.78:

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues which impact fish and wildlife resources and their supporting ecosystems. The mission of the Program is as follows:

1. To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.

2. To gather, analyze, and present information that will aid decision makers in the identification and resolution of problems associated with major land and water use changes.

3. To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decision making process to prevent or minimize the impact of development on fish and wildlife. Biological Services research activities and technical assistance services are based on an analysis of the issues, the decision makers involved and their information needs, and an evaluation of the state of the art to identify information gaps and determine priorities. This is a strategy to assure that the products produced and disseminated will be timely and useful.

Biological Services projects have been initiated in the following areas:

- Coal extraction and conversion
- Power plants
- Geothermal, mineral, and oil shale development
- Water resource analysis, including stream alterations and western water allocation
- Coastal ecosystems and Outer Continental Shelf development
- Systems and inventory, including National Wetlands Inventory, habitat classification and analysis, and information transfer

The Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams which provide the Program's central scientific and technical expertise and who arrange for contracting Biological Services studies with States, universities, consulting firms, and others; Regional staff who provide a link to problems at the operating level; and staff at certain Fish and Wildlife Service research facilities who conduct in-house research studies.

Biological Services Program

FWS/OBS-76/20.9
July 1980

Topical Briefs: Fish and Wildlife Resources and Electric Power Generation, no. 9

COOLING WATER INTAKE SCREENING DEVICES USED TO REDUCE ENTRAINMENT AND IMPINGEMENT

Eugene S. Fritz

National Power Plant Team
2929 Plymouth Road, Room 206
Ann Arbor, Michigan 48105

Power Plant Project
Office of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior

Fish and Wildlife Service

U.S. Department of the Interior

READEX FICHE

best copy available

Mention of trade names in this report does not constitute endorsement or recommendation for use by the Federal Government.

Preface

The series Topical Briefs: Fish and Wildlife Resources and Electric Power Generation is published by the National Power Plant Team of the Power Plant Project to provide a set of concise summaries on topics related to electric power generation and transmission and their effects on fish and wildlife resources. The briefs are written for fish and wildlife biologists who review and make recommendations regarding electric power projects. Each brief contains background information on and a discussion of the particular topic, a selected bibliography of additional information sources, and, in some cases, a strategy to address the problem.

This series is designed to provide synthesized technical information in a convenient format. It is, of course, possible to treat only the basic aspects of each topic within this abridged format. Also, the reader should note that this series addresses solely the technical issues concerning electric power generation and transmission. There may be additional informaton sources and considerations, not covered by this series, which should be incorporated into electric power development decisions.

We solicit open discussion and comment on the topic addressed. Documentation of differing points of view would be appreciated. We request that any suggestions or questions regarding Topical Briefs be directed to:

Information Transfer Specialist
National Power Plant Team
2929 Plymouth Road, Room 206
Ann Arbor, Michigan 48105
(313) 668-2365
FTS: 378-2365

COOLING WATER INTAKE SCREENING DEVICES USED TO REDUCE ENTRAINMENT AND IMPINGEMENT

ABSTRACT

Cooling water intake screening devices that Fish and Wildlife Service personnel may be expected to assess are identified and described. The devices included are modified vertical traveling screens, single-entrance double-exit screens, horizontal traveling screens, passive intake screens, radial wells, artificial filter beds, and porous dikes. For each device the location, limitations or restrictions, evidence for reducing entrainment and impingement, and major unresolved problems are also discussed.

INTRODUCTION

Section 316(b) of the Clean Water Act requires that "... the location, design, construction, and capacity of cooling water intake structures reflect the best available technology available for minimizing adverse environmental impact." The best available technology, exclusive of cost, is most often represented by closed-cycle cooling systems (e.g., cooling towers, ponds, canals) that reduce the volume of water that must be withdrawn from the source of the cooling water. The reduction in the volume of water results in a subsequent decline in the number of organisms drawn toward or into the cooling system, or both. Due to the expense of some closed-cycle cooling systems and their potential environmental impacts (e.g., salt drift, icing, unproductive land use), substantial effort has been expended to identify or develop alternative intake systems and devices.

The purposes of this Topical Brief are to identify and to describe some of the screening devices that Fish and Wildlife Service biologists may be expected to assess, and to discuss the major problems associated with each. The information presented can be used in assessing any type of water intake system including those used in irrigation, industrial, and municipal withdrawals.

Most screening devices or systems presently available can be included within seven general categories. These are: modified vertical traveling screens, single-entrance double-exit screens, horizontal traveling screens, passive intake screens, radial wells, artificial filter beds, and porous dikes. This Topical Brief focuses on each of the categories rather than on the variation found within each.

BACKGROUND

Thermal electric power plants require water to cool steam in their condensers. This water is withdrawn from an external water source (Figure 1). Power plants with a once-through cooling system must withdraw water continuously during plant operation. Among power plants with closed-

cycle cooling systems, make-up water must be withdrawn periodically to replenish that lost by evaporation, blow-down, and other consumptive uses.

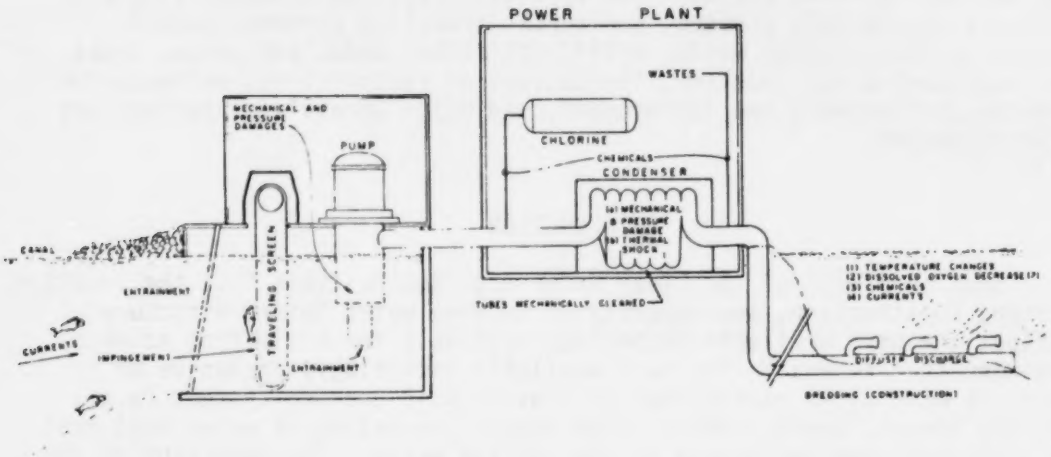


Figure 1. The cooling water system of a thermal electric power plant (Shoreham Nuclear Power Station). The stresses that aquatic organisms encounter in each portion of the cooling system are identified (Coutant 1974).

Cooling water is withdrawn at some type of intake structure, the offshore intake, the shoreline intake, or the approach channel intake (Cada et al. 1979). Somewhere between the point that water enters the intake structure and before it enters the power plant it must pass through a screening device (Figure 1). The original function of the screening device was to exclude debris in the water from entering and clogging the condenser tubes. Inspection of these screening devices showed that many fish and shellfish were held against the screening material (impinged) and many of these organisms died. Further investigation demonstrated that water passing through the screens contained many of the younger and smaller stages of aquatic organisms (entrained). Many of the entrained organisms were killed or made more susceptible to natural mortality as a result of plant passage.

VERTICAL TRAVELING SCREEN

The most common screening device presently being used at power plants, and the device most commonly associated with the impacts resulting

from entrainment and impingement, is the Vertical Traveling Screen (VTS).

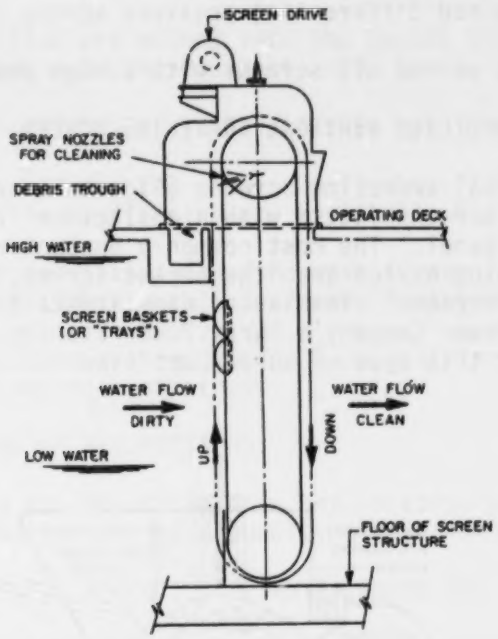


Figure 2. A conventional vertical traveling screen (from U.S. Environmental Protection Agency 1976).

CHARACTERISTICS

Conventional VTS's (Figure 2) may be modified slightly to suit a specific site, but the following characteristics are common to all.

- They are installed in concrete structures that act as the screen and circulating-water pump well.
- Trash bar racks are located ahead of the screen to remove large debris.
- They consist of a chain belt with individual screen panel attached.
- Screens revolve in the vertical plane between a set of two sprockets.
- Screen panels are slightly inclined to retain debris.

- Generally the screen panels are comprised of 9.5-mm woven mesh.
- Screens are rotated either at predetermined intervals or with predetermined differential pressure across the screen.
- Debris is washed off screens with a high pressure spray.

MODIFIED VERTICAL TRAVELING SCREEN

Modified vertical traveling screens (Figure 3) are conventional vertical traveling screens fitted with a collection "bucket" or "pan" beneath the screen panel. The most commonly encountered synonyms for this type of screening device are "the bucket screen," "Ristroph screen," or the "Surry type screen." The latter name arises from the fact that Virginia Electric Power Company's Surry Power Station was one of the original sites that this type of screen was used.

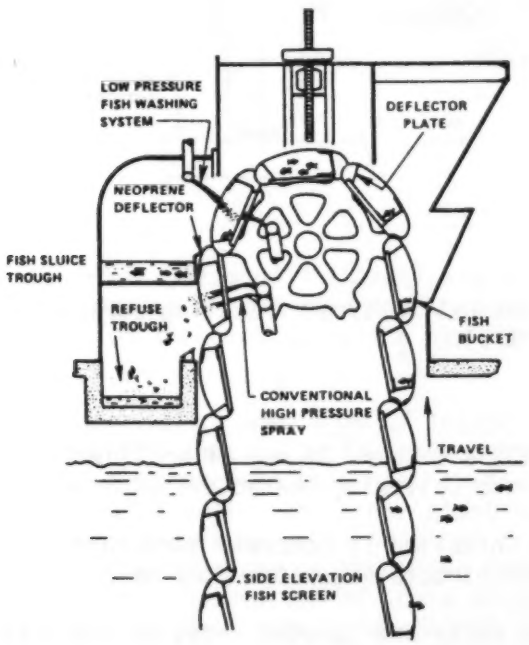


Figure 3. The fish-bucket traveling screens at the Surry Power Station (White and Brehmer 1976).

CHARACTERISTICS

Although there are many variations of the modified VTS's they all have the following characteristics:

- They are structurally similar to conventional VTS's.
- They utilize screen panels that are fitted with a basket capable of retaining water.
- Impinged fish are washed into the basket with a low pressure spray, thus reducing desiccation.
- They typically have a high pressure spray to clean debris.
- They must be operated continuously when fish are present to attain maximum effectiveness (typically 3-6 m/min).
- They must be fitted with fine mesh screen (1 mm or less) to reduce entrainment, this increases impingement.
- They must have a through screen velocity sufficiently low to minimize impingement stress.

LOCATION LIMITATIONS OR RESTRICTIONS

Modified VTS's can be utilized in any location within design limitations of VTS's because the two are structurally almost identical.

EVIDENCE FOR SUCCESSFUL REDUCTION OF ENTRAINMENT AND IMPINGEMENT

A number of in situ impingement studies have been conducted at a number of power plants (Cada et al. 1979). Most of these studies showed a relatively high initial survival rate for impinged fish (as high as 93.3% at Salem Nuclear Generating Station in New Jersey). However, little information has been obtained on long-term or latent survival. One of the few studies that did provide evidence for latent survival was conducted at the Hanford Generating Plant on the Columbia River (Page et al. 1975). In this study 79-95% of the chinook salmon fry, that were released and collected on the screens, survived for over 96 hrs.

In situ studies have not yet been conducted on impingement of larval fishes on fine mesh bucket screens.

PROBLEMS

Evidence from impingement studies suggests that juvenile fishes are less affected by modified vertical traveling screens than by conventional screens. Survival rate, however, appears to be dependent on the physiological characteristics of the organism and hydrological characteristics of the site (e.g., if water is recirculated survival could be reduced by reimpingement or long-term exposure to thermal stress). The physical shape of impinged organism also appears to influence survival rate. For example, filiform larvae tend to become entangled in fine screen mesh (Joseph Johnson, personal communication).

Benefits derived from utilizing modified vertical traveling screens appear to be site specific and dependent on the physiological capacity of a fish to survive impingement force (pinned to the screen) for a certain duration. In order to reduce the duration of impingement, the screens must be continuously operated. Operation in this manner is energy expensive and reduces reliability due to breakdowns resulting from wear of the moving parts.

The use of fine mesh screen panels, and a reduction of the clearance between buckets, shows promise for a reduction in entrainment of fish eggs and larvae. However, reduction of entrainment suggests an increase in larval impingements, the consequences of which are species and life-stage dependent.

SINGLE-ENTRANCE DOUBLE-EXIT VERTICAL TRAVELING SCREENS

In single-entrance double-exit vertical traveling screens (Figure 4) water enters the center of the screen and passes from the inside to the outside of the screening surface. Thus debris and biota are impinged on the inner surface of the screen. The most common device is the pear-shaped Passavant Screen which has been used in Europe for over 30 years.

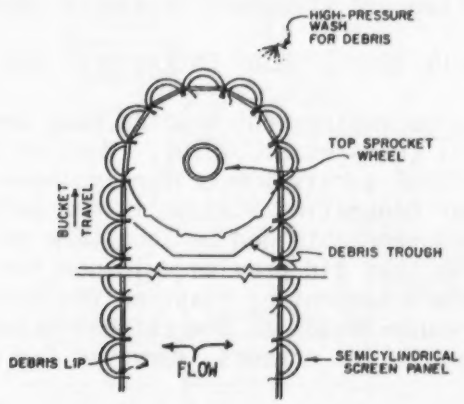


Figure 4. A single-entrance double-exit screen (Magliente et al. 1978).

CHARACTERISTICS

The major characteristics of single-entrance double-exit screens are:

- The screen surface is theoretically double that of a comparable conventional VTS.

- Various shapes of screen panels can be utilized but the semi-circular screen basket fitted with a water proof membrane and water retaining lip (Figure 5) appears most promising for impact reduction (Magliente et al. 1978).

- Screen baskets can be constructed of any mesh size, however, 0.5-mm fine mesh or smaller is the most effective for reducing entrainment impacts on larval fish and eggs.

- The system has a low pressure wash to flush eggs and larvae into the water retaining portion of the bucket.

- The top of the system has a high pressure spray wash which directs debris, fish eggs, larvae, and post larval stages of fish to a collecting trough which returns them to the receiving water.

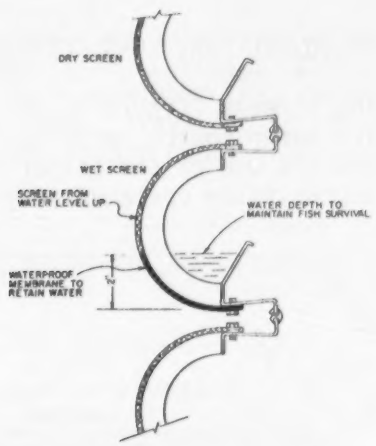

DRY SCREEN
WET SCREEN
SCREEN FROM WATER LEVEL UP
WATER DEPTH TO MAINTAIN FISH SURVIVAL
WATERPROOF MEMBRANE TO RETAIN WATER

Figure 5. Semi-circular screen basket used in single-entrance double-exit screen systems (Magliente et al. 1978).

LOCATION LIMITATIONS OR RESTRICTIONS

Based upon manufacturers' claims, single-entrance double-exit screens can be used in any site that will accommodate a conventional VTS.

EVIDENCE FOR SUCCESSFUL REDUCTION OF ENTRAINMENT AND IMPINGEMENT

Only one *in situ* study has been completed (Barney M. Davis Generating Station, Corpus Christi, Texas) which evaluated the effectiveness of single-entrance double-exit screens; 86% of the impinged organisms survived. Although survival appears high, one must realize that all observations were made 10-15 min after collection. No results were available for latent mortality or for survival rates of larvae.

PROBLEMS

Results of the study conducted at the Barney Davis Generating Station (Murray and Jinnette 1978) do not indicate that the single-entrance double-exit screen is any more effective in reducing impingement mortality than is the modified VTS. The use of fine mesh screen (0.5-mm slot size) should reduce entrainment, but cause simultaneous increase in impingement of fish eggs and larvae. Any fish impinged on the down-travel side of the screen would also remain impinged for a longer period than those on the up-travel side. Although results of the Barney Davis study suggest increased survival rates among fishes (juveniles and larger), no field data have been obtained which demonstrates that larval impingement survival rates are greater than entrainment survival rates.

The keyhole shape of the Passavant Screen can itself contribute to higher incidence of impingement because the required screen well can act as an entrapment device.

HORIZONTAL TRAVELING SCREENS

Horizontal traveling screens (Figure 6) are continuously moving screens that traverse the water source being screened. Although much discussion has surrounded the use of the latter screening device, such screens have not been successfully operated at power plants.

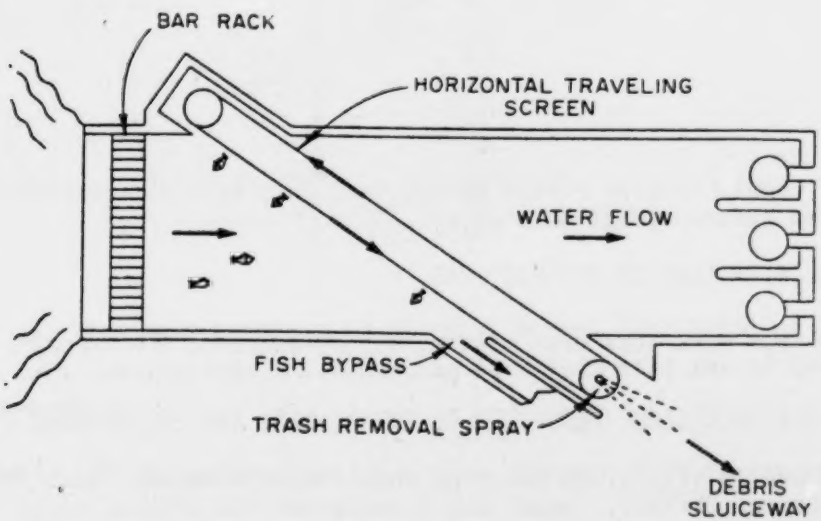


Figure 6. Vertical view of the original design concept for horizontal traveling screens in steam-electric power plant intakes (Chezar 1976).

CHARACTERISTICS

Although many designs have been developed for horizontal traveling screens, they all have the following in common:

- The screening surface remains submerged thoughout each cycle.
- The screen is usually oriented at some angle (usually between 20° and 30°) to the flow.
- Fish and shellfish impinged on or approaching the screen are carried or directed to a return or bypass system.
- Screens can be fitted with fine mesh to reduce larval entrainment.

LOCATION LIMITATIONS OR RESTRICTIONS

Horizontal screens have the potential for being utilized at any location that can accomodate conventional vertical traveling screens. A number of designs have been developed that can be used with a very short canal although most horizontal traveling screen prototypes indicate the need for a relatively long intake canal (Figure 7).

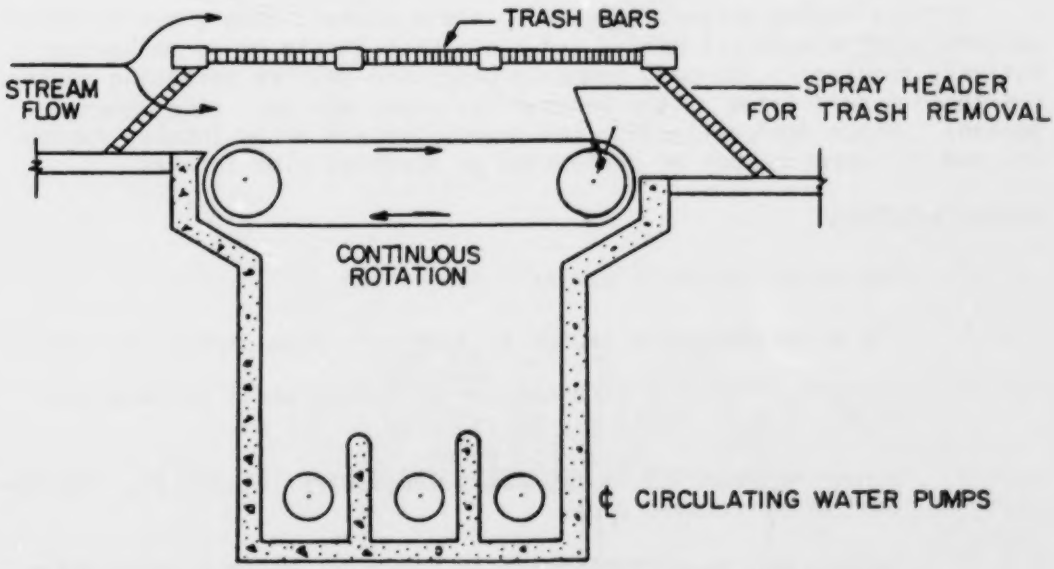


Figure 7. A screenwell with flushmounted horizontal traveling screen (U.S. Environmental Protection Agency 1976).

EVIDENCE FOR SUCCESSFUL REDUCTION OF ENTRAINMENT AND IMPINGEMENT

The evidence for reduced impingement mortality comes from experiments with prototypes (Cada et al. 1979). These experiments yielded results that showed over 90% diversion efficiency and survival rates of impinged fry and fingerlings between 39% and 100% (the experiments utilized chinook salmon, Oncorhynchus tschawtyscha, fry and fingerlings). Little evidence has been developed for biological effectiveness of full-scale screens.

PROBLEMS

The results of experiments with prototypes are insufficient to evaluate the effectiveness of the horizontal screens to reduce the impact of entrainment and impingement.

One of the major problems that has not yet been solved, particularly in areas with fluctuating high and low water levels, is mechanical reliability. The screens must move continuously to operate appropriately and effectively. Most of the prototype systems have had problems with excessive mechanical wear.

PASSIVE INTAKE SCREENS

Passive intake screens (Figure 8) are a generic name given to those devices which screen-out debris and biota with little or no mechanical activity required. The most commonly discussed passive screening systems are those manufactured by the Johnson Division, UOP Inc. (the Johnson Screen). Other devices include the Ranney Surface Water Intake, Ranney Co. and the large number of perforated or screened pipe intakes.

CHARACTERISTICS

- The screening units are self supporting.
- The screening units can be cylindrical, drum shaped, or panels.
- Screens are mostly fine mesh or with very small perforations (0.5 - 2 mm). Slots may be as large as 9.5 mm.
- Screening material is typically wedge wire (Figure 9), "Smooth-tex" or perforated pipe.
- Systems may be self-cleaning in locations where flowing water passes by the screens, but most utilize back-up backflushing components.

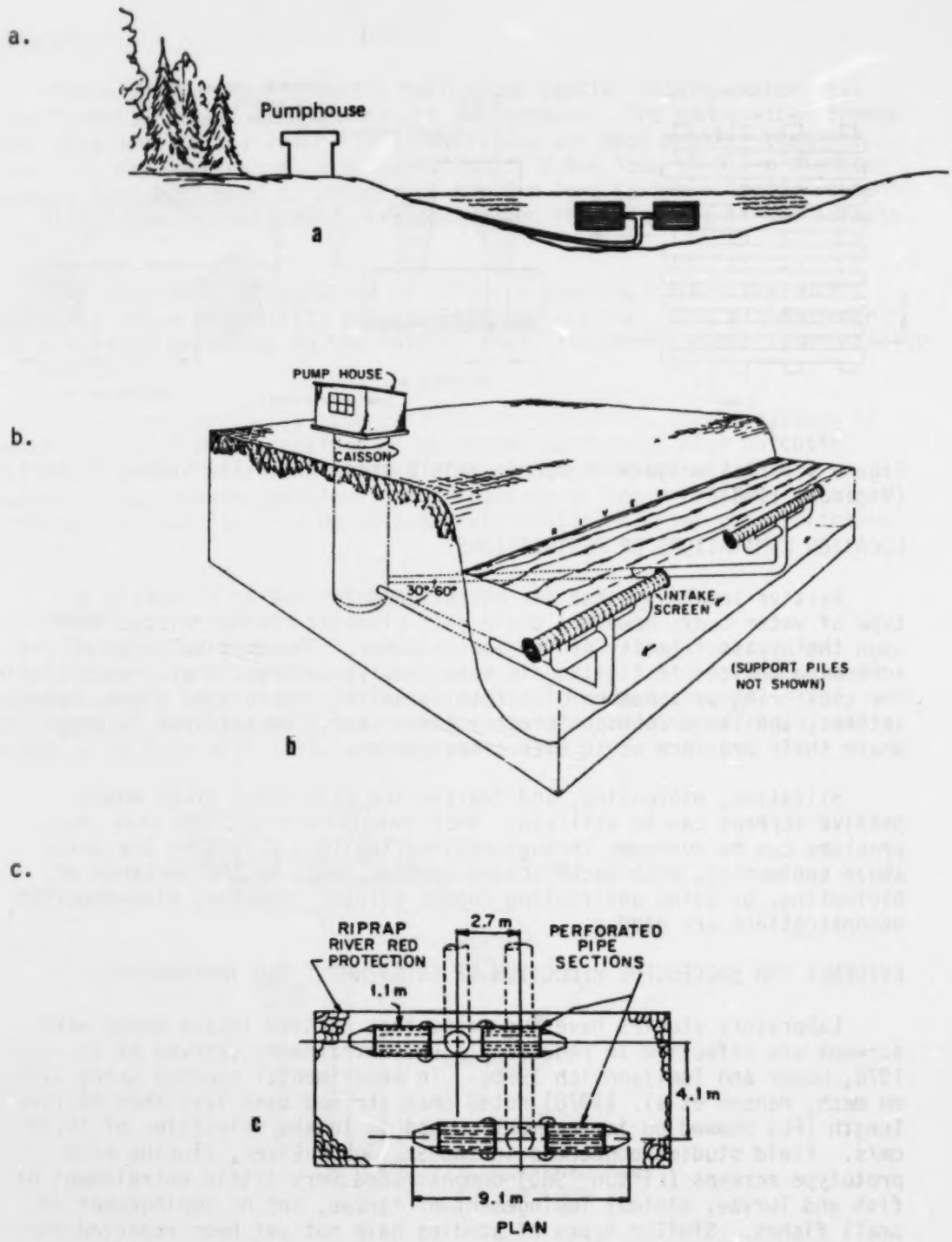


Figure 8. Passive intake screens: (a) design concept for cylindrical wedge-wire screens at power plant cooling-water intakes (Pagano and Smith 1979), (b) a Ranney surface water intake (Mickels and Bennett 1978), (c) a perforated pike intake system (Richards and Hronich 1976).

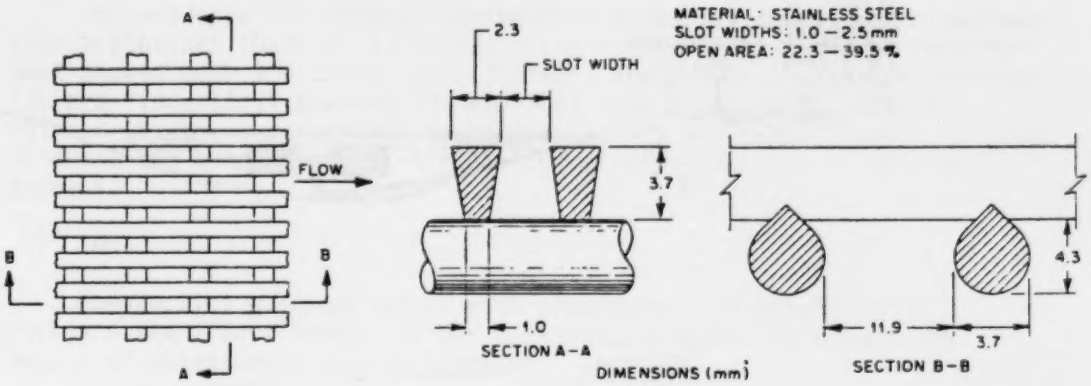


Figure 9. Flat wedge-wire screen panels used in the TVA hydraulic test (Vigander 1978).

LOCATION LIMITATIONS OR RESTRICTIONS

Passive intake systems can be designed for use in virtually any type of water body; however, their self cleaning characteristic depends upon the bypass velocity of the source water. The physical size of the screening devices is limiting in most passive systems, thus, necessitating the clustering of a number of screening units. Perforated pipes, Ranney Intakes, and large Johnson Screen intakes cannot be utilized in areas where their presence would affect navigation.

Siltation, biofouling, and frazzle ice also limit areas where passive screens can be utilized. Most manufacturers claim that these problems can be overcome through engineering (e.g., raising the units above sediments), with backflushing systems, and, in the instance of biofouling, by using antifouling copper alloys. However, site-specific demonstrations are needed.

EVIDENCE FOR SUCCESSFUL REDUCTION OF ENTRAINMENT AND IMPINGEMENT

Laboratory studies have indicated that passive intake wedge wire screens are effective in reducing larval entrainment (Hanson et al. 1978, Heuer and Tomljanovich 1978). In experimental studies using 1.01-mm mesh, Hanson et al. (1978) noted that striped bass less than 40 fork length (FL) showed no impingement stress at intake velocities of 15.24 cm/s. Field studies conducted in the St. Johns River, Florida with prototype screens (Lifton 1980) demonstrated very little entrainment of fish and larvae, minimal impingement of larvae, and no impingement of small fishes. Similar types of studies have not yet been reported for other types of passive screening systems.

PROBLEMS

There is no evidence that a full-scale passive intake system will significantly reduce entrainment and impingement. The wedge wire screens that have been tested under field conditions are much smaller than the type that may be eventually employed (e.g., 0.6-m long by 0.3-m diameter screens have been used as prototypes for 6-m long by 3-m diameter screens). The difference in scale makes evaluating the effectiveness of the screens difficult.

The size and configuration of offshore passive intakes are such that they could potentially act as artificial reefs. Such a phenomenon, could attract organisms to the intake, thus, increasing their vulnerability to impacts.

As stated previously, the utilization of passive intake systems in water with high concentrations of suspended particles, high potential for frazzle ice formation, or high biofouling potential may pose a number of maintenance problems. The solution of these problems requires information that can only be obtained at facilities using passive intake systems.

RADIAL WELLS

Radial wells (Figure 10) are subsurface collectors located in highly permeable alluvial aquifers where the water table is high and in direct contact with a surface stream or lake (recharge source). The most popular brand name is the Ranney Collector. Yields of radial wells range up to 0.93 m^3/s (Mikels and Bennett 1978).

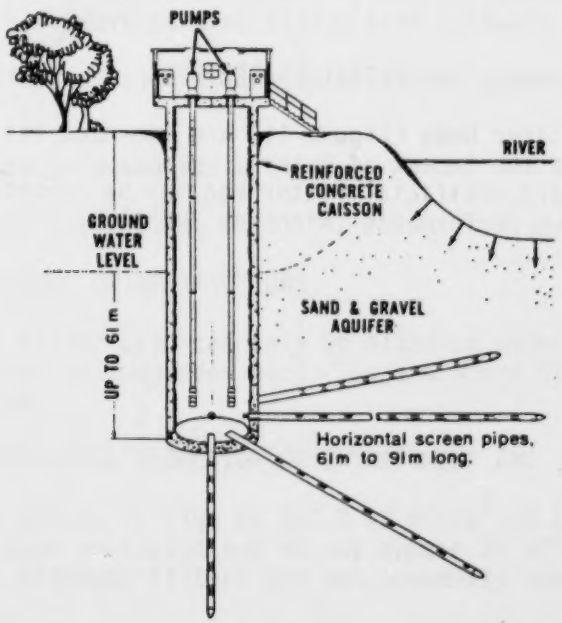


Figure 10. A radial well intake system (Ray et al. 1976).

CHARACTERISTICS

The fundamental characteristics of the radial well intake are:

- A submerged concrete caisson sunk into the base of an aquifer adjacent to a recharge source.
- A number of perforated pipes that radiate from the base of the caisson into the aquifer.
- A pump to move water from the well to the plant.

LOCATION LIMITATIONS AND RESTRICTIONS

Radial wells can only be located in sand or gravel aquifers that are connected hydrologically with the recharge source. If the system is to provide a reliable source of water, the recharge source must be at a higher level than the aquifer.

EVIDENCE FOR SUCCESSFUL REDUCTION OF ENTRAINMENT AND IMPINGEMENT

Water is obtained directly from the aquifer, thus, aquatic resources are not affected unless the recharge source is reduced to a level that results in degradation of aquatic habitat.

PROBLEMS

The major problem associated with radial wells is the necessity to locate them in a sand or gravel aquifer. The volume of water that can be obtained is limited by the aquifer and the recharge source. These problems limit the application of radial wells to relatively specific areas.

ARTIFICIAL FILTER BEDS

Artificial filter beds (Figure 11) are man-made filtering facilities designed to reduce the impact of water withdrawals on aquatic organisms. The state-of-the-art artificial filter bed may be capable of providing 3.1 m^3/s at maximum performance (Richards 1978).

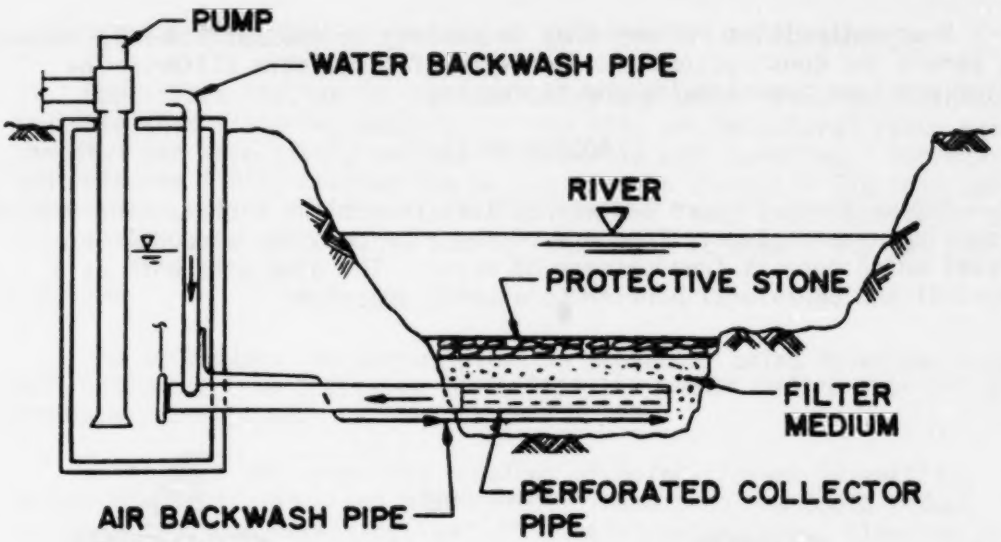


Figure 11. An infiltration barrier intake (Richards 1978).

CHARACTERISTICS

- A large excavated area filled with suitable filter material.
- A perforated pipe or series of pipes imbedded in the filter material.
- A pumping facility.
- A backflush system.

LOCATION LIMITATIONS OR RESTRICTIONS

Artificial filter beds can only be sited on water bodies that have low concentrations of suspended particles and where the potential for biofouling is low.

EVIDENCE FOR SUCCESSFUL REDUCTION OF ENTRAINMENT AND IMPINGEMENT

Filtration waters as high as 407.3 l/ min/m^2 (0.61 cm/s filter velocity) have been evaluated and do not appear to affect juvenile fish (Stober 1978). Although filters are not presently operational at a

power plant site, some engineers believe that filters can eventually be designed to effectively eliminate entrainment and impingement of fish eggs and larvae.

PROBLEM

Most authorities believe that technology is not sufficiently advanced to permit the construction and operation of a reliable filter. The major problems are clogging and biofouling.

POROUS DIKES

Porous dikes (Figure 12) are filters resembling a breakwater surrounding a cooling water intake. The core of the dike consists of cobble or gravel which permits free passage of water. The dike acts both as a physical and behavioral barrier to aquatic organisms.

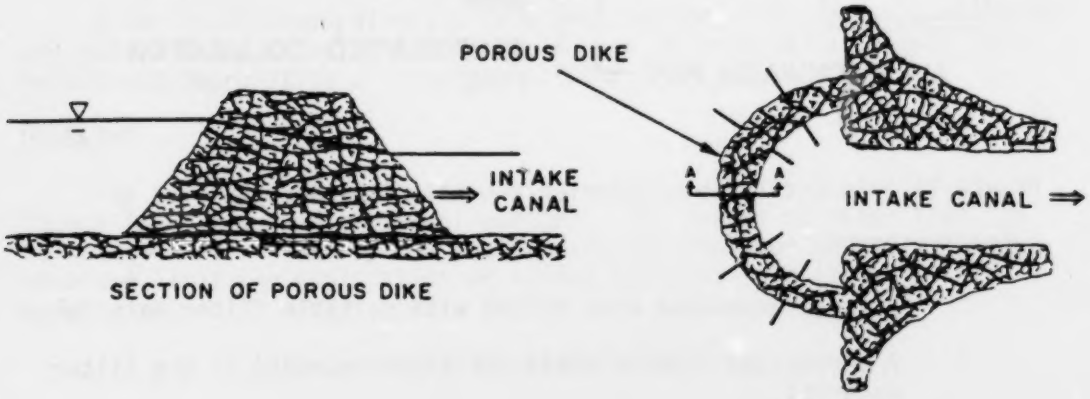


Figure 12. A Gabion dam (Schrader and Ketschke 1978).

CHARACTERISTICS

The main characteristics of porous dikes are:

- The filtering mechanism includes a breakwater or some other type of barrier and the filtering core. Both components can be built of the same type and size material.
- Filtering material must be a size that permits free passage of water but still prevents entrainment and impingement.

LOCATION LIMITATIONS OR RESTRICTIONS

Porous dikes can be utilized in large lakes and coastal areas. However, this type of screening device may have limited application in areas with high concentration of suspended particles and biofouling potential.

EVIDENCE FOR SUCCESSFUL REDUCTION OF ENTRAINMENT AND IMPINGEMENT

Controlled studies in the laboratory and under field conditions indicate that filtering material of the dike and behavioral responses to the dike can effectively exclude fish larvae and juveniles. Schrader and Ketschke (1978) studied the porous dike at Wisconsin Electric Service Company's Lakeside Plant on Lake Michigan and found that numerous fish penetrated large void spaces but for most fish accessability was limited

PROBLEMS

The technology for porous dikes is presently being developed and much evidence, from operating facilities, is needed before they can be thoroughly evaluated.

Dikes have the potential problems of being clogged by settling suspended particulates and biofouling. These problems could reduce reliability, thus necessitating costly maintenance (e.g., cleaning or biociding). The dike can also act as an artifical reef, thereby attracting organisms and increasing the potential for some type of adverse impacts (e.g., increased predation, mortality due to biocide additions, increased fishing pressure).

CONCLUSION

Closed cycle cooling systems reduce the volume of cooling water withdrawn from a water body by at least 90% of that required for once-through cooling systems. In estimating the effectiveness of closed cycle cooling with once through cooling systems fitted with a VTS, Boreman et al. (1979) concluded that closed cycle cooling minimizes the biological impact by at least 90%. To be considered an alternative to closed cycle cooling a once-through cooling system with its screening device must be shown to reduce impingement and entrainment mortality by 90% of that expected of a once through system fitted with a VTS.

The intake technologies described in this topical brief show some promise for reducing the impacts of entrainment and impingement. However, evidence is insufficient to demonstrate that any of these intake systems alone, or in combination, can afford the protection that is presently attainable by closed cycle cooling. The most effective systems, the radial well and artificial filter bed, can only provide enough water for make up water in closed cycle systems. The screening devices, both active and passive, do not yet have a sufficient data base to demonstrate

effectiveness or reliability. More experience is needed operating and maintaining these devices before they can be considered as alternatives to closed cycle cooling for minimizing the adverse impact of cooling water intakes.

Another subject, that must be considered when assessing screening devices which require the impingement of an organism, is the fish bypass or return system. The success of the screening system is greatly dependent on returning or bypassing fish, eggs, and larvae to the source water with a high probability for their survival. Any system that minimizes damage to organisms during their capture, but damages or overly stresses them when released, cannot be considered the best technology available. Similarly, a system that returns organisms to an area that is unsuitable for their survival cannot be considered best technology available. Fish return systems differ greatly at different power plants. These differences have inhibited the evaluation of the return portions of water intake systems.

REFERENCES

Boreman, J., L. W. Barnthouse, D. S. Vaughan, C. P. Goodyear, and S. W. Christensen. 1979. Entrainment Impact Estimates for Six Fish Populations Inhabiting the Hudson River Estuary. Joint Testimony. Prepared for the U.S. EPA. Region II. no pagination.

Cada, G. F., J. B. Cannon, and D. W. Lee. 1979. Alternative Screening Devices at Indian Point Units 2 and 3, Bowline Point, and Roseton Generating Stations. Joint Testimony Prepared for the U.S. EPA Region II. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 138 pp.

Chezar, B. 1976. Mutifarious Power Plant Water Intake Structure (MWIS) - A Design Concept to Reduce the Environmental Effects of Cooling Water Intake Structures. New York State Energy Research and Development Authority, 164 pp.

Coutant, C.C. 1974. Opening remarks at entrainment and intake screening workshop: "Evaluation of entrainment effect", pp. 1-11. In Proceedings of the Second Workshop on Entrainment and Intake Screening. EPRI, Publ. 74-049-00-5.

Hanson, B. M., W. H. Bason, B. C. Beitz, and K. E. Charles. 1978. Practicality of profile-wire screen in reducing entrainment and impingement, pp. 195-233. In Larval Exclusion Systems for Power Plant Cooling Water Intakes. Proceedings of the workshop held 7-8 February, 1978. San Diego, California.

Heuer, J. H., and D. A. Tomljanovich. 1978. A study on the protection of fish larvae at water intakes using wedge-wire screening, pp. 169-194. In Larval Exclusion Systems for Power Plant Cooling Water Intakes. Proceedings of the Workshop held 7-8 February, 1978. San Diego, California.

Lifton, W. S. 1980. Biological Aspects of Screen Testing on the St. Johns River, Palatka, Florida. Dames and Moore, Cincinnati, Ohio. 14 pp.

Magliente, S. H., D. A. Tomljanovich, J. H. Heuer, S. Vigander, and M. N. Smith. 1978. Investigations on the protection of fish larvae at water intakes using fine-mesh screening. Impingement release concept: Laboratory study of single-entrance double-exit, vertical traveling screen concept, pp. 69-77. In Larval Exclusion Systems for Power Plant Cooling Water Intakes. Proceeding of the Workshop held 7-8 February, 1978. San Diego, California.

Mikels, F. C., and T. W. Bennett. 1978. Cooling water intakes utilizing Ranney Collectors and Ranney Intakes, pp. 15-25. In Larval Exclusion Systems for Power Plant Cooling Water Intakes. Proceedings of the Workshop held 7-8 February, 1978. San Diego, California.

Murray, L. S., and T. S. Jinnette. 1978. Survival of dominant estuarine organisms impinged on fine-mesh traveling screens at the Barney M. Davis Power Station, pp. 79-87. In Larval Exclusion Systems for Power Plant Cooling Water Intakes. Proceedings of the Workshop held 7-8 February, 1978. San Diego, California.

Pagano, R. and H. B. Smith. 1977. Recent developments in techniques to Protect aquatic Organisms at the Water Intake Steam-electric power plants. Report 7671. Prepared for the MITRE Corporation, Milean, Virginia. 74 pp.

Page, T. L., R. H. Gray, and E. G. Wolf. 1975. Report on Impingement Studies Conducted at the Hanford Generating Project - March and April 1976. Report to Washington Public Power Supply System. Battelle - Northwest, Richland, Washington. 9 pp.

Ray, S. S., R. L. Snipes, and D. A. Tomljanovich. 1976. A State-of-the Art Report on Intake Technologies. Report PRS-16, EPA-600/ 7-76-020. Prepared by the TVA for the U.S. EPA, Washington, D.C. 82 pp.

Richards, R. T. 1978. Engineering constraints in the use of artificial filter beds, pp 5-12. In Larval Exclusion Systems for Power Plant Cooling Water Intakes. Proceedings of the Workshop held 7-8 February, 1978. San Diego, California.

Richards, R. T. and M. J. Hronich. 1976. Perforated-pipe water intake for fish protections. J. Hydra. Div. Proc. Am. Soc. Civ. Eng. 102 (HY2):139-147.

Schrader, B. P., and B. A. Ketschke. 1978. Biological aspects of Porous-dike intake structures, pp 51-63. In Larval Exclusion Systems for Power Plant Cooling Water Intakes. Proceedings of the workshop held 7-8 February, 1978. San Diego, California.

Stober, Q. J. 1978. High-capacity filters for power plant cooling water intakes, pp. 13-14. In Larval Exclusion Systems for Power Plant Cooling Water Intakes, Proceeding of the workshop held 7-8 February, 1978. San Diego, California.

U.S. Environmental Protection Agency. 1976. Development Document for Best Technology Available for the Location, Design, Construction, and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact. Report EPA 440 1-76 015-a. Washington, D.C. 263 pp.

Vigander, S. 1978. Current TVA work on the fluid mechanics of screens with very small openings for the exclusion of larvae at power plant cooling water intakes, pp 91-105. In Larval Exclusion System for Power Plant Cooling Water Intakes. Proceedings of the workshop held 7-8 February, 1978. San Diego, California.

White, J. C., and M. L. Brehmer. 1976. Eighteenth-month evaluation of the Ristroph Traveling fish screens, pp 376-380. In Proceedings of the Third National Wordshop on Entrainment and Impingement: Section 316 (b) - Research and Compliance. E. A. Communications. Melville, New York.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

Stock No. 024-010-00553-0

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980-654-500

TOPICAL BRIEFS ISSUED

FWS/OBS-76/20.1. Impacts of Power Plant Intake Velocities on Fish.

FWS/OBS-76/20.2. Transmission Line Rights-of-Way Management.

FWS/OBS-76/20.3. Mathematical Methods to Evaluate Entrainment of Aquatic Organisms by Power Plants.

FWS/OBS-76/20.5. Federal Water Pollution Control Act: The Sections 316(a) and 316(b) Process.

FWS/OBS-76/20.6. Effects of Geothermal Energy Development on Fish and Wildlife.

FWS/OBS-76/20.7. Factors Affecting Accuracy of Ichthyoplankton Samples Used in Power Plant Entrainment Studies.

FWS/OBS-76/20.8. The Clean Air Act: Its Relation to Fish and Wildlife Resources.

FWS/OBS-76/20.9. Cooling Water Intake Screening Devices Used to Reduce Entrainment and Impingement.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

UNITED STATES
DEPARTMENT OF THE INTERIOR
Fish and Wildlife Service
National Power Plant Team
2929 Plymouth Road, Room 206
Ann Arbor, Michigan 48105

Official Business
Penalty for Private Use $300

Postage and Fees Paid
U.S. Department of the Interior
INT 423